Simulation of Transient Over-voltage from Energization of Unloaded Transmission Line

Bidemi Awogbemi   **Advisor: Michael Omidiora**
Department of Electrical Engineering
University of Bridgeport, Bridgeport, CT

Abstract

In power systems, energized transmission line when slightly loaded unloaded, or open-circuited (disconnected), the voltage at the receiving-end will often be greater than the voltage at the sending-end. This phenomenon is known as Ferranti Effect. This paper investigates transient overvoltage caused by energization of unloaded transmission line based on analysis, and EMTP-ATP modeling and simulation. Solution to reduce and control overvoltage is demonstrated using shunt reactor compensation technique.

Introduction

Energized medium voltage and long transmission lines when slightly loaded or open-circuited will present a voltage at the receiving-end that exceeds the voltage at the sending-end. This increase in voltage is accounted for by the capacitive line charging current drawn by the transmission line which builds up over long distance. Since electrical loads both generate and absorb reactive power, therefore, during normal operation, the load, which is mostly inductive, will absorb the reactive power generated by the capacitive charging current drawn by the transmission line and the system is considered self-regulating in such condition. On the other hand, since load varies from time to time, light load or open-circuit when presented to the system, the inductive load may not be sufficient or unavailable to absorb the reactive power delivers by the capacitive line charging current, hence it builds up as overvoltage at the receiving-end, causing an unacceptable transient condition. For this reason, transmission lines need to be compensated to balance varying reactive power and to improve voltage profile.

Transmission Line Under Consideration

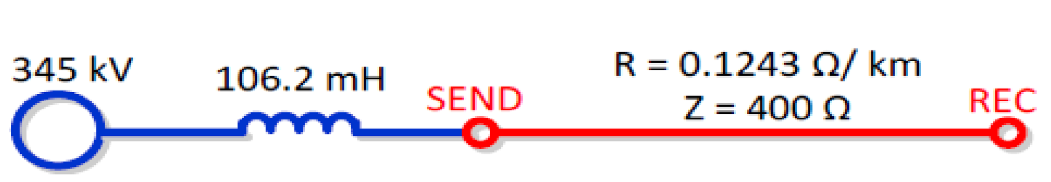

Fig.1: A single line representation of a 345kV transmission line

Line above is modeled as distributed lump parameter with the following data and assumptions:

Single-Phase representation assumed
Source voltage = 1pu
Frequency, f = 60Hz

Line lengths modeled are: 100km, 200km, 300km, 400km, 500km, 600km, 700km, 800km and 900km.

Transmission Line Model

Line charging characteristics for different line lengths calculated are shown in Tab. 1.

Line (km)	C(μF)	Xc(Ω)	MVAR
100	0.83	3183	37.4
200	1.67	1592	74.8
300	2.49	1061	112.2
400	3.32	796	149.6
500	4.15	637	187.0
600	4.98	531	224.4
700	5.81	455	261.8
800	6.64	398	299.2
900	7.47	354	336.6

Tab.1: Charging characteristics for different line lengths

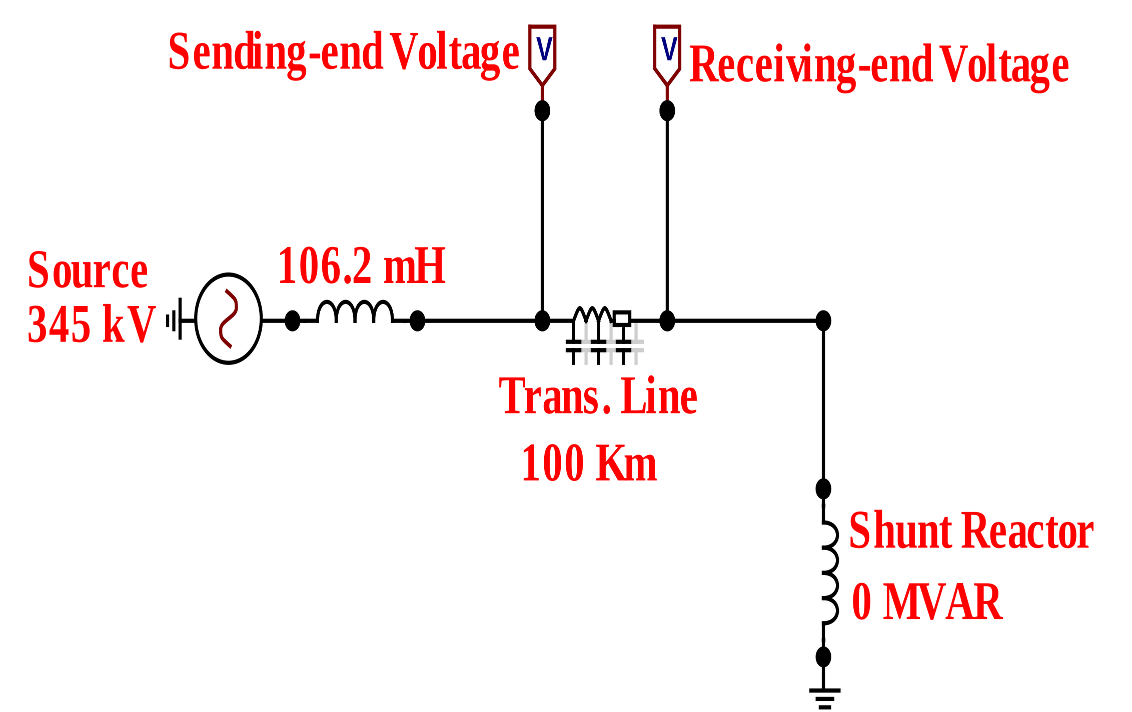

Fig.2: Single-phase model : Uncompensated 100km transmission line

Mitigation Technique

Line compensation in this work was achieved using specified shunt reactors of various sizes (MVAR) as shown in Tab.2. Based on MVAR sizes, reactance and inductance for different line lengths were estimated. Results obtained are shown in Tab. 2. Model for 100km line is shown in Fig.3.

MVAR	XL(Ω)	L(mH)
100	1190	3157
150	794	2105
200	595	1579
250	476	1263
300	397	1052

Tab. 2: Inductive reactance and line inductance for different shunt reactor sizes.

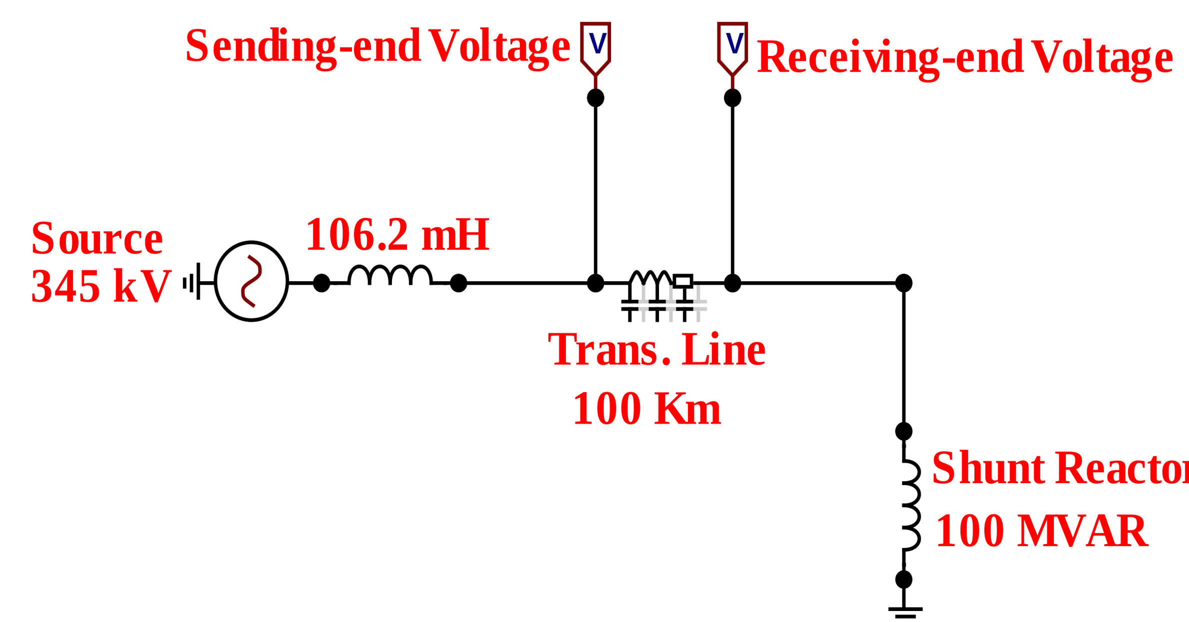

Fig.3: Single-phase model: Compensated 100km transmission line

Discussion & Results

Modeling and simulation were carried out for specified shunt reactors, i.e. 0, 100, 150, 200, 250 and 300MVAR. Results for uncompensated line (0 MVAR) are shown in Tab. 3. Modeling and simulation were repeated for other shunt reactor sizes. Results obtained are shown in Fig. 4.

EMTP Simulation Result (0MVAR)

Line (km)	V_S	V_{SEND}	V_{REC}	V_{REC}/V_{SEND}
100	1	1.0128	1.0209	1.0080
200	1	1.0264	1.0596	1.0323
300	1	1.0413	1.1196	1.0752
400	1	1.0582	1.2064	1.1400
500	1	1.0782	1.3292	1.2328
600	1	1.1031	1.5030	1.3625
700	1	1.1357	1.7534	1.5439
800	1	1.1807	2.1229	1.7980
900	1	1.2456	2.6709	2.1443

Tab.3: Ferranti Effect EMTP simulation results for 0MVAR
All above voltages are in per unit (p.u)

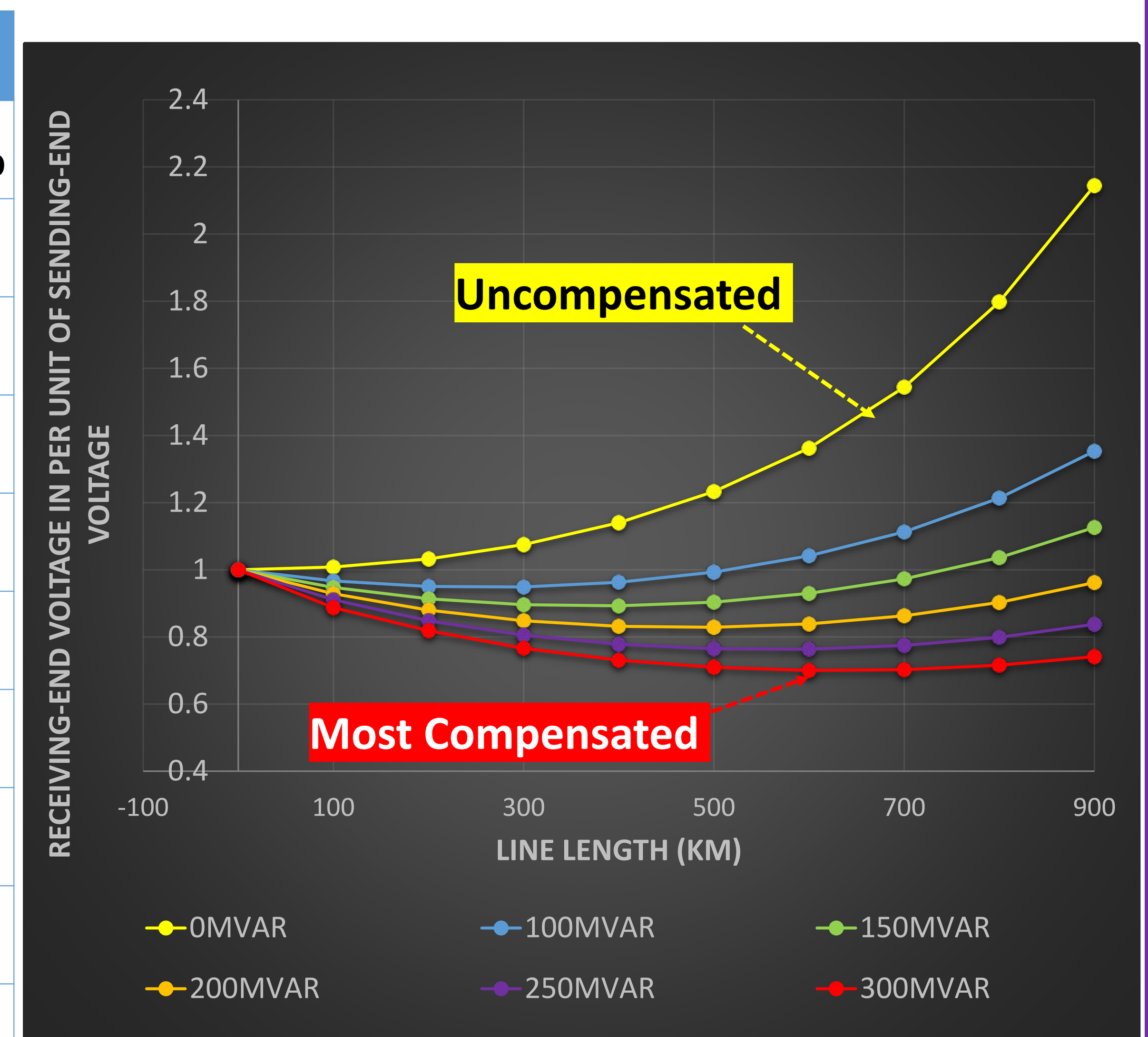

Fig.4: Rise in receiving-end voltage for an unloaded 345kV line for different line lengths (uncompensated and compensated) of various sizes of shunt reactors . The above voltages are in per unit (p.u)

Conclusion

As shown above, the receiving-end voltages of unloaded lines are abnormally higher than the sending-end voltages due to imbalance in reactive power. Since load varies from time to time, the reactive power on transmission lines also vary. To balance the reactive power and improve voltage profile, adequate size of shunt reactor is required to compensate for inductive reactive power during unloaded or lightly loaded condition.

References

[1] Gagari Deb, " Ferranti Effect in Transmission Line", *International Journal of Electrical and Computer Engineering (IJECE), Vol.2, No.4, August 2012,pp-447-451, ISSN:2088-8708.*

[2] J.N.Rai, Naimu Hasan, B.B Arora, Ajendra Signgh, Tapesh, "Enhancement of Voltage Profile of Transmission Line by Using Static VAR Compensator – A case Study.", *National Electrical Engineering Conference(NEEC-2011) and Energy Systems for Tomorrow".*

[3] Reshma Tarannum, Rashmi Singh, "Reducing Ferranti Effect in Transmission Line using Dynamic Voltage Restorer", *International Conference on Science and Engineering for Sustainable Development (ICSESD-2017), Special Issue-1, ISSN:2454-1311*